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(54) ENERGY ABSORBING DEVICE

(71) We, TOYOTA JIDOSHA KOGYO KABUSHIKI KAISHA, a Corporation duly organized under the laws of Japan, of 1, Toyota-Cho, Toyota-shi, Aichi-ken, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to an energy absorbing device which may be used with the steering wheel, seat fixing, or bumper-connecting means of a vehicle for safety of the vehicle operator and protection from any unusual force imparted from outside the vehicle on collision thereof. The recent increase in speed and power of automobiles has made it socially important to safeguard the car and its occupants during inadvertent collisions which often cause serious injuries to the driver, or other occupants of the vehicle. In conventional vehicles unequipped with retractable steering wheels, the driver lurches forward due to inertia at the instant of collision and strikes his breast sharply against the steering wheel.

The present invention is intended to overcome this problem by providing an energy absorbing device in the car which, for example, may be attached to the steering shaft of the vehicle and to a part of the vehicle chassis or other fixed supporting member on the vehicle. Alternatively, the energy absorbing device may be assembled with other parts of the vehicle, such as the seat fixing means, or the bumper connection means, so as to absorb the external collision force effectively and avoid injury to the driver, or other occupants of the vehicle. Destruction of vehicle parts, other than a part of said device, is also avoided.

The device according to the invention comprises a receiving member for transmission of an external force, an energy absorbing member having an end portion fixed to said receiving member, and having another end portion adapted to be secured to a supporting member, said energy absorbing member being formed of a metal or a material having similarly high resistance to plastic deformation and being provided with a plurality of spaced narrow slits extending substantially normal to the line of action of said external force, the edges of said slits lying in close or abutting relation, said energy absorbing member being plastically deformable in one direction but rigid against deformation in the opposite direction so that an external force of a magnitude greater than a predetermined value applied to the receiving member in said one direction will plastically deform the energy absorbing member so as to open said slits.

Preferably, said energy absorbing member comprises a device having an elongated plate, said slits being spaced apart in lines perpendicular to the longitudinal axis of the plate, the slits of one line being staggered relative to those of the adjacent line.

It will be appreciated that the invention provides an energy absorbing device which has relatively simple components, is easy to produce and economical to manufacture, and which, after absorption of energy from an external force, can be replaced simply by replacing, or reconstituting by plastically deforming, the deformed portion of the device for repeated operations.

The invention will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, wherein like reference characters indicate like parts throughout the several Figures, and in which:

Figure 1 is a plan view of the energy absorbing device according to the invention for incorporation in a steering rod assembly such as that of Figure 5;

Figure 2 is a plan view showing the energy absorbing device of Figure 1 after it has been stretched to absorb shock, or collision energy;

Figure 3 is a bottom plan view of another embodiment of the invention to be incor-

porated between the bumper and chassis of a vehicle;

Figure 4 is a side elevation of the embodiment of Figure 3;

Figures 5 to 7 are examples of the application of the embodiment of Figure 1 to the steering wheel of a vehicle, in which Figure 5 is a side elevation with parts broken away and in section; Figure 6 is a cross-sectional view taken along line VI—VI in Figure 5; and Figure 7 is a cross-sectional view taken along line VII—VII of Figure 1.

Referring now to the drawings, Figures 1 and 2 show a shock absorbing device according to the invention and which is of general application. Figure 5 shows the same device as part of the steering rod assembly of an automobile. The steering device A comprises a telescopic steering shaft formed in upper and lower members or portions 5a and 5b coaxial with and surrounded by a telescopic, tubular steering post, or column, in which the shaft rotates. Combined with these is an energy absorbing member and supporting parts generally indicated by the reference character B. The steering wheel device is shown installed in an automobile having conventional parts such as a steering gear box C, steering wheel D, body or chassis E, a firewall separating the engine and the driver compartments and having a lower portion, or toe plate 1, and an instrument panel 2. The gear box C is rigidly fixed to the chassis in a conventional manner, not shown. The upper portion 5a of the steering shaft is connected to the steering wheel D, while the lower portion 5b is connected to the gear box C through a conventional flexible joint 3 so as to transmit the torque of the steering wheel to the gear box. The lower steering shaft portion 5b passes through a low friction ring 4 positioned about an opening in the toe plate 1, and the upper portion 5a is connected to the instrument panel 2 through the energy absorbing device B, as will be more fully explained later. The tubular steering post 6 (Fig. 5) has two telescopic portions, 6a and 6b, respectively surrounding the corresponding telescopic portions 5a and 5b of the shaft.

The steering shaft upper portion 5a is formed as a bar, while the lower portion 5b is a cylindrical tube, both being arranged to have a common axis. The lower end of portion 5a is telescopically fitted into the upper end of portion 5b, so as to be capable of extending and retracting in the axial direction, but relative rotary motion is restricted so as to transmit the steering torque. Particulars of this construction are presented in Figure 6 in which the member 5a has a circular cross-section flattened at opposite diametrical areas to present parallel, planar sides. The cylindrical member 5b is correspondingly flattened to receive the member 5a with a close fit. Thus, the members 5a and 5b can telescope, or slide axially with respect to each other, but both must revolve together without relative rotary motion. During manufacture, synthetic resin 7 is injected under compression between the fitting surfaces of the members 5a and 5b through a small hole 5c provided on the lower member 5b, while said members 5a and 5b are fitted together so as to remove play during rotation.

The upper end of steering shaft 5 is connected to the steering wheel D and rotates in ball bearings 8 held from axial movement by snap rings 9 and 10. The outer race of ball bearings 8 is fastened to the upper steering column member 6a. A dust keeper 11 is provided at the lower end of the steering shaft member 5b to prevent the entrance of dust, mud, water, etc.

The steering column upper member 6a is of larger diameter than the lower member 6b, being coupled at 12 for telescopic movement, and the two members are arranged coaxial with the steering shaft 5. The coupling 12 involves closely interfitting the lower end of 6a to the upper end of 6b in such manner that they may move relative to one another to extend or retract the column 6 in the axial direction. A synthetic resin is injected into the coupling under compression between the fitting surfaces of 6a and 6b through a small hole 6c in the upper member 6a during manufacture. The interfit at the coupling is sufficiently tight as normally to prevent relative axial movement of the members 6a and 6b, as well as bending in the absence of an unusual force such as is engendered in a collision. The moulded synthetic resin 7 will in no way obstruct the relative extension and retraction movements of the members 5a, 5b, and 6a, 6b when subjected to collision forces, the resin yielding to permit relative sliding movements with slight friction between the respective portions of the steering shaft and steering column.

The lower steering column member 6b is loosely fitted through the hole in toe plate 1 surrounded by the friction ring 4. This ring is closely fitted to the outer periphery of member 6b and connected to the toe plate by an annular attaching member 70 secured by bolts. The ring 4 supports the lower member 6b to be immovable radially without preventing movement in the axial direction. A dust keeper 13 is provided between the steering shaft 5b and steering column member 6b to prevent entrance of dust, mud, water, etc., into the steering column 6.

The steering column upper portion 6a constitutes a receiving member and is attached to the instrument panel 2 (which constitutes a supporting member) through the energy absorbing member B as illustrated in detail in Figures 1, 2 and 7. The energy absorbing member, per se, is a semi-circular plate designated 14, having a lower projecting

tongue 19 which is rigidly fastened to the member 6a by bolt 17 and small friction bushings 15 and 16, Figure 5. The bolt 17 passes through an elongated slot 18 disposed axially of the tongue. Normally, the bolt 17 is tightened adjacent to the upper end of the slot 18, as shown in Figure 1.

A pair of projecting tongues 20 are formed at the upper end of plate 14. Each tongue is longitudinally slotted at 23, 24 to receive a bolt 22, which, as shown in Figure 7, passes through the slots and holds plate 14 and spacer guide 21 to the instrument panel 2. Normally, the bolts 22 are fastened approximately in the middle of slots 23 and 24. On the upper steering column member 6a are welded internally threaded, cup-like spacers 25 to which are secured a semi-circular bracket 26 by threaded bolts 27. The bolts pass through apertures in the bracket and firmly secure the latter to member 6a. Each guide 21 is somewhat elongated to overlie a substantial portion of the adjacent tongue 20. A longitudinal groove 28 is provided in the inner side surface of the guide and an end tab of said bracket 26 is slidably fitted in the groove through the small friction member 29. The guide members 21 are fixed to the instrument panel 2 by means of the bolts 22 which pass through openings therein. Since the fastening bolts 22 are spaced from the bracket grooves 28, the bracket can move in the grooves longitudinally of the guide members 21 relative to the instrument panel either upwardly or downwardly parallel to the axis of the steering column 6.

The lower tongue 19 of the energy absorbing plate 14, as shown in Figure 5, has a low friction bushing 15 disposed between itself and the spacer collar 71 projecting from the outer periphery of the steering column member 6a, and another low friction bushing 16 between the washer on the bolt 17 and the tongue 19. The bolt is threaded to spacer 71 whose lower end is welded, or otherwise firmly secured to the steering column member 6a.

The upper end of the steering column member 6a has an inverted cup-like cover 30 integrally coupled therewith, which cover carries and supports the outer race of the ball bearings 8 rigidly fixed by their inner race to the steering shaft upper portion 5a. Consequently, the steering column 6 rotatably supports the steering shaft 5.

The energy absorbing element, or plate 14, secured by tongues 19, 20, as above described, is formed as a semi-circular plate of metal, metal alloy, or other suitable rigid, but slightly resilient material such as sheet steel. The mid-portion 31 of plate 14 is made plastically deformable to absorb energy by provision of a plurality of narrow slits 32 preferably disposed in parallel lines, with the slits of adjacent lines staggered. Certain of the slits open to the side edges of plate 14. The lines of slits are perpendicular to the axial direction of the steering assembly as shown in Figure 1, whereby a number of strips, partly interrelated with each other, are delineated by the slits. The edges, or walls of the slits 32 are in close abutting, or nearly abutting contact with each other, so that the said mid-portion 31 is rigid against compressive force exerted axially on the upper and lower tongues 20 and 19, and such forces will not vary the length of the plate 14. However, tensile axial forces, exceeding a predetermined value, when exerted on the tongues 19, 20 result in plastic deformation, causing plate 14 to take a grid form, as shown in Figure 2, the slits opening wide to form spaces 34, and the length of plate 14 is increased. By such plastic deformation into grid form, the load energy is absorbed in the amount desired, or required.

The steering device, as described above, operates as follows. Upon accidental collision, when the vehicle operator's chest strikes the steering wheel D, the upper steering shaft member 5a moves downwardly and retracts into the lower member 5b. With movement of the upper steering shaft member 5a, the steering column upper member 6a will slide downwardly axially over the lower member 6b. During such retraction movements of the members 5a and 6a, the energy absorbing plate 14 fastened between the upper member 6a and the instrument panel 2 will have its mid-portion 31 elongated by the resultant tensile force. The plastic deformation of portion 31 of the energy absorbing member 14 absorbs the kinetic energy of the steering shaft 5 produced by the collision.

The described action of absorbing energy will be amplified as follows. When the operator is thrown toward the steering wheel D and the striking force thus produced exceeds a predetermined value, there will occur a sliding in the telescopic fitting portions of the connected parts opposed by little friction. That is, in the wheel shaft 5, the synthetic resin 7 permits retraction of the upper member 5a opposed only by moderately small frictional forces between the interfitting portions of the upper and lower members 5a and 5b, and also in steering column 6 the coupling 12 permits retraction of the upper member 6a opposed only by moderate friction forces between the interfitting portions of the upper and lower members 6a and 6b. The bracket 26 integral with the steering column upper mmber 6a slides downwardly along the groove 28 of the guide member 21, attached to the instrument panel 2 by bolt 22, and is opposed by a small amount of friction through the low friction member 29. Thus, the interfitting portions of the steering shaft and column pass from a static frictional condition to a dynamic, small frictional move-

ment, whereupon the bolt 17 holding the member 6a will move to contact the lower end 33 of the slot 18 and carry the tongue 19 downwardly, stretching the energy absorbing mid-portion 31 of the plate 14 so as to open the slits 32 and thereby absorb the desired energy. Thus, the plate 14 is plastically deformed gradually into grid form with widened spaces 34 defining said slits. This plastic deformation absorbs the shock of the operator striking the wheel. Therefore as the chest of the operator strongly strikes the steering wheel, the absorption action of plate 14 soaks up the energy of collision in such a way that the operator is protected against damage, to a large extent.

An upward movement of the steering assembly A is caused by a frontal collision when the front portion of the chassis is deformed and the gear C is moved rearwardly. The rearward movement of said gear box C is transmitted upwardly to the lower steering shaft portion 5b through the flexible joint 3. Under this condition the upper steering shaft portion 5a transfers much of the force of collision upwardly in the axial direction to the energy absorbing plate 14 through the ball bearings 8, cover 30, and upper steering column portion 6a. Since the energy absorbing plate 14 is not plastically deformable under compressive loads, the mid-portion 31 of said absorbing member 14 will remain rigid, while the upper steering column portion 6a remains relatively fixed, being prevented from upward movement by the fastening to the instrument panel 2. Thus, the respective lower members 5b and 6b will retract upwardly into the upper members 5a and 6a without raising the wheel D to strike the operator, so that his safety is guarded, as it is in the reverse situation wherein the operator is thrown downwardly against the steering wheel D.

As may be understood from the preceding description, a novel feature of the invention resides in that the energy absorbing element is not an integral part of the steering shaft assembly A, nor even a surrounding coaxial part, as has been employed conventionally, but instead is a separate unit individually disposed between the steering shaft and a chassis, or body portion of the vehicle. This makes it possible to reuse the energy absorbing unit, or to replace the absorbing unit if the steering shaft assembly A remains connected and unharmed after a collision. By provision of a separate and individual energy absorbing member it is also possible to apply such member to all varieties of cars, even though having different steering shaft assemblies, so long as they require the same amount of energy absorbtion, whereby larger quantities of absorbing members can be produced, and their cost lowered.

In Figures 3 and 4 is shown an embodiment of the invention adapted to be mounted between the bumper and chassis of a vehicle and thereby to absorb the energy of collision by plastic deformation of the bumper and the energy absorbing member 14 when a force of collision shock is exerted on the bumper in the direction of the arrow Y. The mounting means comprises a supporting member 60b fixed to the chassis (not shown) by any conventional means, and the bumper (also not shown) fixed to the receiving member 60a. Member 60a is a heavy shaft slidable in the sleeve 60b. A link 62 of channel cross-section has one end pivoted at 61 to member 60a and the other end 66 fastened to absorbing plate 14a by bolt 17. A second link 64, of channel cross-section, has one end pivoted at 63 to the sleeve member 60b and the other end 67 fastened to the plate 14a by the bolt 22. The two links 62, 64 are crossed at their centers, preferably, and are pivoted on shaft 65. The energy absorbing member 14a corresponds exactly to plate 14 of Figures 1 and 5, except that it is flat, rather than curved. It will be seen in this embodiment that the energy absorbing member 14a resists deformation in the direction of compression when the members 60a and 60b are moved toward each other. When the force of shock is in the direction of tension of the members, i.e., the members 60a and 60b tend to separate, and when the separating force exceeds a predetermined value, the energy absorbing member 14a will be elongated by plastic deformation, spreading, or opening the slits 32 in the manner previously explained for the corresponding slits of the absorbing member 14, Figures 1 and 2.

Thus in the preferred devices of the present invention, plastic deformation of the plate 14 or 14a can be produced by an external impact or force and energy is absorbed when the longitudinal directions of the slits 32 are normal to the direction of working of the external force, if the material and size of the energy absorbing plate and the size and number of the slits 32 are properly selected. The tensional force producing the plastic deformation becomes large with the diminishing of the angle formed between the direction of the force and the longitudinal axis of the plate 14. The amount of energy absorbed can be determined by the arrangement and interspaces of the slits 32. It is possible to provide the initial tensional force and the amount of energy absorption by suitable preselection of the material and thickness of the energy absorbing member, and the locations and spacings of the slits. Thus, the energy absorbing member is of simple construction and its assembly with the parts to be protected is also non-complex, so that the energy absorbing plate can be widely used in many places and its use is not restricted to automative vehicles.

The longitudinal directions of the slits 32

should not coincide with, or be parallel with the direction of action of the shock force, or the direction of sliding of the force-receiving and supporting members, because this would prevent plastic deformation and opening of the slits. Therefore, the longitudinal directions of the slits must not agree with the sliding direction of the said two force-receiving and supporting members, but preferably, should be in a crosswise, or a normal direction to the collision force.

It will be apparent from the above that the energy absorbing member of the invention is preferably designed as a plate-shaped member with closed, or nearly closed slits therein. A shock force plastically deforms the energy absorbing member to open the slits. Even though the initial tension producing the plastic deformation is large, the movement of the receiving member relative to the supporting member is small, so that the device is adapted for energy absorption where the amount of energy for absorption and the initial tension are large while the allowable amount of deformation, and relative sliding movement of the supporting and force-receiving members are small.

WHAT WE CLAIM IS:—

1. An energy absorbing device comprising a receiving member for transmission of an external force, an energy absorbing member having an end portion fixed to said receiving member, and having another end portion adapted to be secured to a supporting member, said energy absorbing member being formed of a metal or a material having similarly high resistance to plastic deformation and being provided with a plurality of spaced narrow slits extending substantially normal to the line of action of said external force, the edges of said slits lying in close or abutting relation, said energy absorbing member being plastically deformable in one direction but rigid against deformation in the opposite direction so that an external force of a magnitude greater than a predetermined value applied to the receiving member in said one direction will plastically deform the energy absorbing member so as to open said slits.

2. An energy absorbing device according to claim 1, wherein said energy absorbing member comprises an elongated plate, said slits being spaced apart in lines perpendicular to the longitudinal axis of the plate, the slits of one line being staggered in relation to those of the adjacent line.

3. An energy absorbing device according to claim 2, wherein selected ones of said slits open to the side edges of said plate.

4. An energy absorbing device according to either of claims 2 or 3, wherein said energy absorbing plate has a curved configuration.

5. A energy absorbing device according to either of claims 2 or 3, wherein said energy absorbing plate is flat.

6. An energy absorbing device substantially as herein described and shown in Figs. 1, 2 and 5 to 7 of the accompanying drawings.

7. An energy absorbing device substantially as herein described and shown in Figs. 3 and 4 of the accompanying drawings.

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3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG.1.

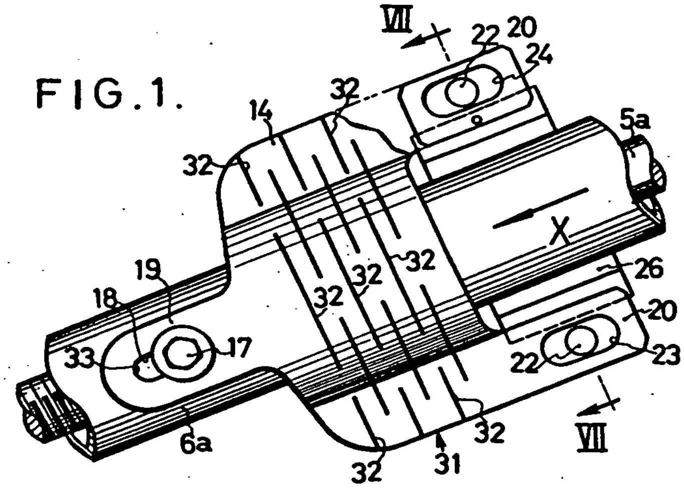
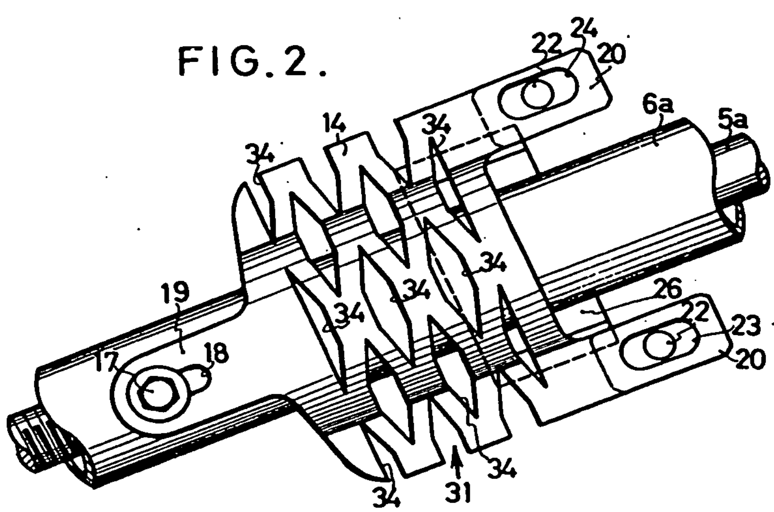


FIG.2.



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Sheet 2

FIG. 3.

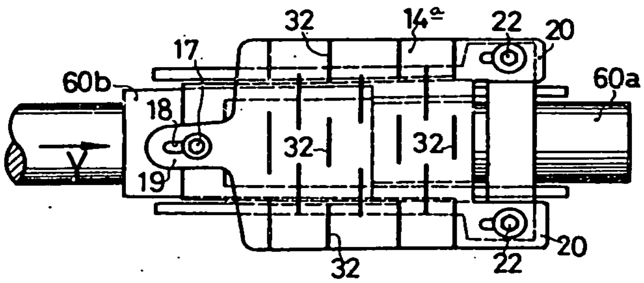


FIG. 4.

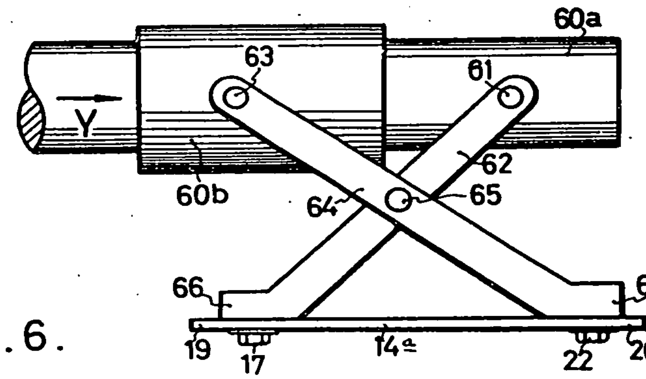


FIG. 6.

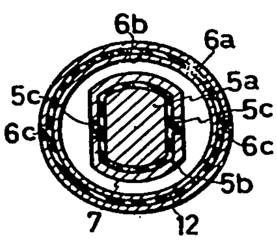
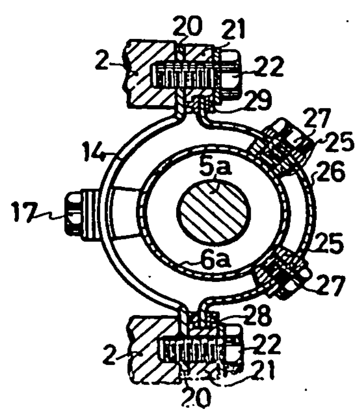


FIG. 7.



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Sheet 3

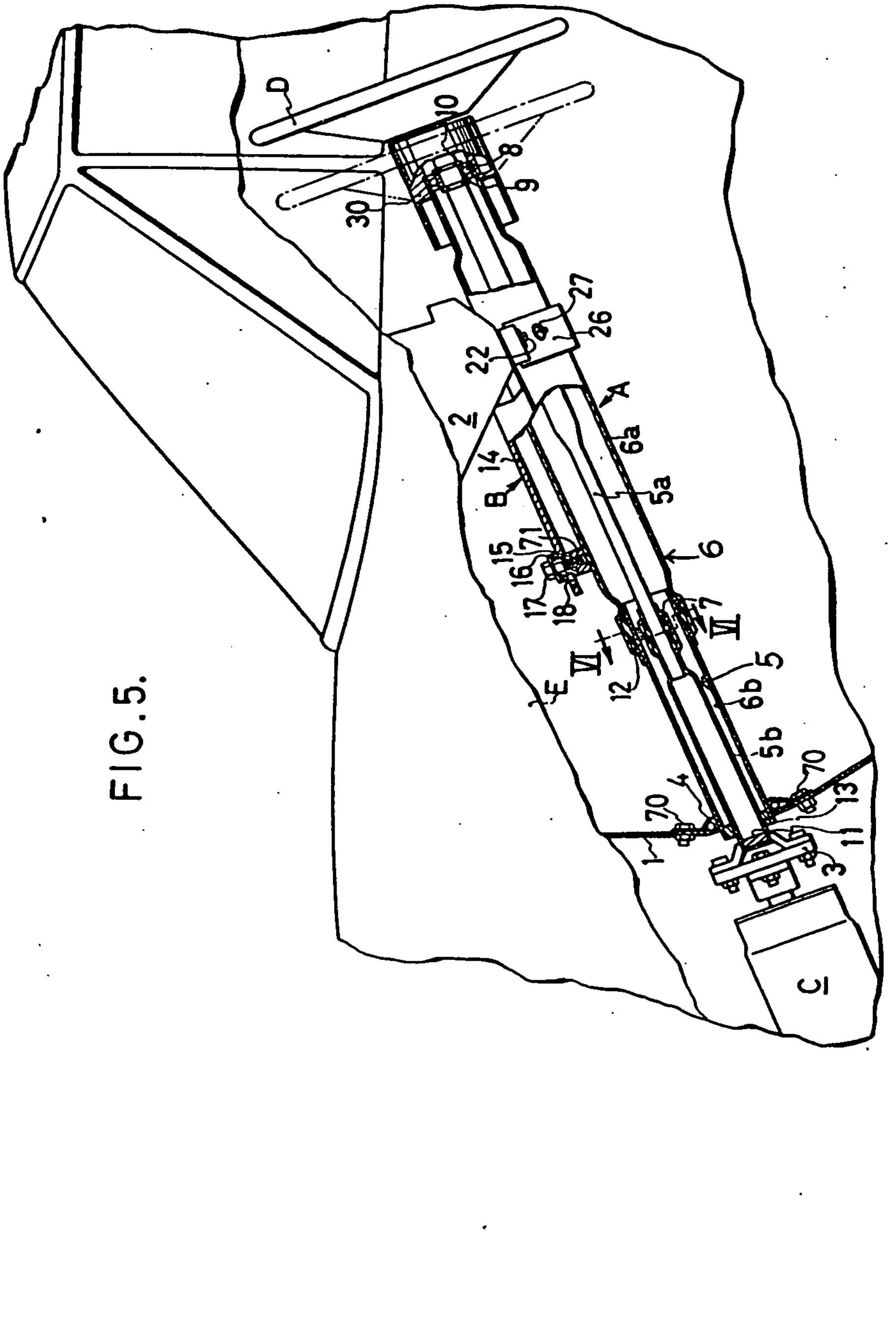

FIG.5.